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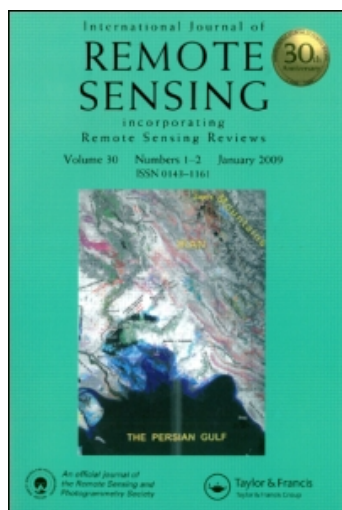
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### WATeRS: an open Web Map Service with near-real time MODIS Level-2 standard chlorophyll products of the North Sea

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## Letter

# WATeRS: an open Web Map Service with near-real time MODIS Level-2 standard chlorophyll products of the North Sea

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WATeRS (<http://ivm10.ivm.vu.nl/mapserver/WATeRS>) is a portal for near-real time (NRT) satellite-derived water quality (chlorophyll) information products that is openly and interactively available for all on the Internet. It is based on automated conversion of remotely sensed data (in scientific formats) to geographic information system (GIS) formats, and comprises a customized Arc Internet Map Server (ArcIMS) application with an OpenGIS compliant Web Map Server connector. The resulting GIS-based open map service comprises a simple, clear and intuitive user interface, grid-cell query functionality, and is complemented by a metadata catalogue that provides full lineage of the chlorophyll maps, and automated archiving. WATeRS enables users to interactively explore remote sensing products, and to seamlessly combine this with other geographical data.

## 1. Introduction

Phytoplankton concentrations can be estimated with remote sensing techniques because of the spectral characteristics of the chlorophyll pigment. The MODerate Resolution Imaging Spectroradiometer (MODIS) is a 36-band spectrometer observing the land, atmosphere and oceans within a wavelength range from 412 to 14385 nm (Esaias *et al.* 1998). Chlorophyll data from MODIS Aqua Level-2 Local Area Coverage (LAC) data products are brokered in compressed scientific data format from NASA's Ocean Biology Processing Group (A.2, Appendix). Standard MODIS Aqua Level-2 chlorophyll-a (CHL) concentrations are retrieved with the MODIS Chlor\_a\_3 semi-analytical algorithm (equation (1)), which uses the spectral absorption properties of phytoplankton in the surface waters (O'Reilly *et al.* 2000).

$$\text{CHL} = 10.0^{(0.2830 - 2.753R_{3M} + 1.457R_{3M}^2 + 0.659R_{3M}^3 - 1.403R_{3M}^4)} \quad (1)$$
$$R_{3M} = \log_{10}(R_{550}^{443} > R_{550}^{490})$$

where  $R_{3M}$  is the maximum reflectance (or satellite band) ratio.

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Notwithstanding attempts to make data and software openly available to all (McClain *et al.* 2004), the use of remote sensing is principally limited to specialists. We consider that this is partly due to the format in which the datasets and derived products are available, the scientific software required to work with them, and a certain lack of context within which these datasets are offered.

In recent years, presentation of maps on the Internet (Web mapping) has developed from static view-only pictures, to open and interactive vector geographical information system (GIS)-based mapping (Plewe 1997, Gittings 1999, Kraak and Brown 2001, Green and Bossomaier 2002, Mitchell 2005). Vector and image (raster) Web mapping are still developing independently, mainly because of the differences in data formats and underlying database structures (Gittings 1999, Tsou 2004).

Semiautomated mapping of parameters estimated from remote sensing and subsequently serving these as (georeferenced) pictures on the Internet is nowadays common practice for space agencies. In addition, near-real time (NRT) satellite services have been set up using the X-band receiving systems capable of capturing direct broadcast data (Shutler *et al.* 2005). However, in our view users might benefit from an end product that requires an extension of the processing chain (Eleveld *et al.* 2003b) and creation of an NRT Web mapping application that allows users to interact with the data derived from remote sensing.

The objectives of this work were therefore to provide NRT CHL information estimated from satellite sensor data, available openly and interactively for all on the Internet, based on automated conversion of satellite data (in scientific formats) to GIS formats, and customization of an Arc Internet Map Server (ArcIMS) application with a an OpenGIS compliant WMS Web Map Server (ArcIMS-OGC WMS) connector. WATeRS should enable users to explore interactively the remote sensing products, and to seamlessly combine the data with other geographic data. The open character should be compliant with the geodata infrastructures (Nebert 2004). It should adhere to the request for context through metadata, additional GIS layers and hyperlinks.

## 2. Method

We developed several programs to import, convert, project and subsequently serve and update remote sensing data in open GIS compliant format in an NRT Web mapping application (figure 1). The first program enables the data to be semiautomatically downloaded from an Ocean Color ftp site, where NRT MODIS-Aqua data are staged in zipped hdf format, and geocorrects unflagged CHL data (to a lat-lon grid) using IVM's (Matlab) software library routines. A second program converts the resulting .mat files into ASCII grid files, and copies those to the server. The latest five are stored in a separate folder. An Arc Macro Language (AML) program contains instructions to project these files (to UTM 31N, WGS84), write the resulting ESRI GRID files to a folder, and move datasets older than 30 days to the WATeRS archive.

To provide the data, standard technology has been used, that is ESRI ArcIMS Web mapping software. Mapservice configuration files are AXL (Arc eXtensible markup Language, a specific type of XML) pages determining which and how GIS layers are displayed.

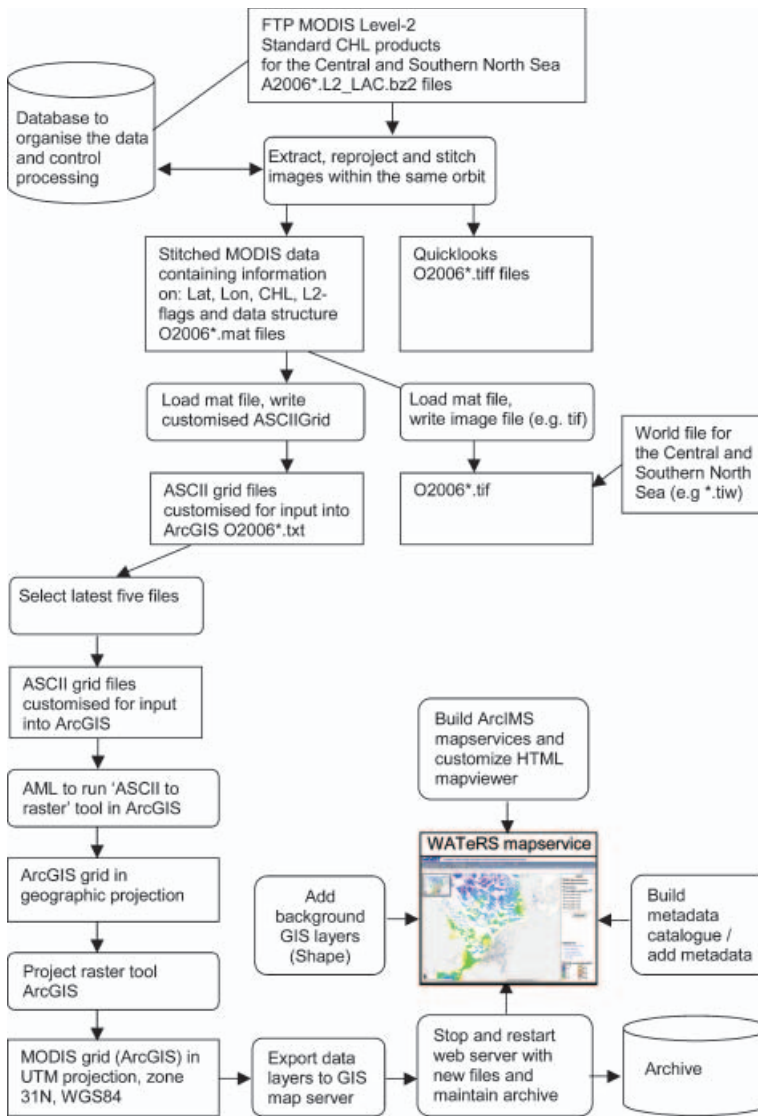


Figure 1. Processing flow from retrieval of MODIS Level-2 data zipped scientific data to brokerage in a map service.

The ArcIMS image services standard viewer (A.4, Appendix) and application were customized by:

- Altering the HTML and JavaScript files that make up this ArcIMS HTML mapservice;
- Adding spatial bookmarks for monitoring stations;
- Displaying legends in a separate popup box;
- Enabling CHL legend colour classification (A.7);
- Layer management through an unfold mechanism for the group layers (A.1);
- Identifying grid cell values with the information button (A.5).

A desktop PC with a client program (PuTTY) was used for service updating, that is to stop, restart, remove, add and refresh specific map services over our network via SSH, Telnet and Rlogin network protocols.

Metadata, additional GIS layers and links to additional datasets for the North Sea offer integrated contextual information on the remote sensing datasets. A metadata catalogue (A.4) with the following characteristics was developed:

- Conform the minimum set of mandatory metadata elements for CEN ENV 12657;
- Full textual description of metadata elements;
- Flexible Access database, but limited interoperability, that is without direct exchange with other metadata catalogues or tools;
- Updateable anytime, anywhere (via the Internet).

An open service was created by enabling the WMS ArcIMS-OCG connector for the WATeRS service. For use in an ArcGIS Desktop environment, our ArcIMS server (A.4) can be added. For other software (e.g. MapInfo Professional 8.0), perform a GetCapabilities request followed by retrieval via the WMS ArcIMS-OCG connector (A.4). The ArcIMS Multi-Service Viewer (A.4), one of the sample ArcIMS HTML viewers provided by ESRI, allows combination of map services and use of spatially overlapping datasets (e.g. A.3). The open WMS is already compliant with modern geodata infrastructures, and a purely open source GIS counterpart (Mitchell 2005) is in development (A.4).

### 3. Results

The main result is the WATeRS portal itself, <http://ivm10.ivm.vu.nl/mapserver/waters/>. The service enables interactive exploration of remote sensing products in combination with other geographic data. Using the portal would best illustrate this, but alternatively a screen dump is presented as an example. Interaction with WATeRS takes you from an overview of CHL patterns to CHL concentrations placed in context through comparison with *in situ* measurements (figure 2). Techniques used include interaction with ArcIMS and specific WATeRS tools, notably unfolding group layers, using spatial bookmarks for zooming, retrieving the information on cell values, and using a hyperlink to additional data.

Standard ArcIMS technology also enables simple vector GIS analyses in WATeRS to be performed, such as searching for monitoring stations within a certain zone (buffer) around the 12-mile (22 km) zone delineating Dutch territorial waters.

### 4. Discussion and conclusions

Water quality parameters exhibit important spatiotemporal variability that can be detected well with remote sensing monitoring techniques. NRT provision of data derived from remote sensing in suitable (open) GIS or model formats may encourage further use for spatial planning at sea (designation of marine parks); monitoring environmental quality (eutrophication); supporting operational oceanography (NRT cruise planning); (shell) fisheries; and input for modelling (data assimilation).

The service has been created for MODIS L2 standard CHL products of the North Sea, but the procedure could easily be adapted for other parameters, algorithms and sensors, or other regions:



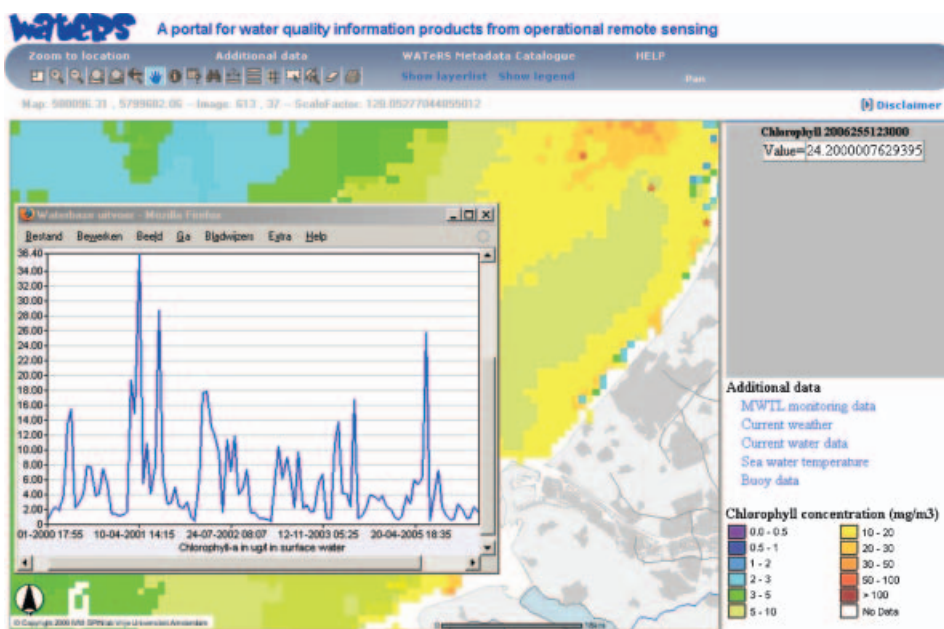


Figure 2. A CHL raster cell value on the location of MWTL station Noordwijk 20, obtained via the information button, compared with historical *in situ* monitoring data (A.6, Appendix) available via a link under Additional data.

- Using the MODIS Level-2 products to derive Sea Surface Temperature (SST) would require replacing CHL by SST in the code. Other MODIS or SeaWiFS products can also simply be incorporated in the processing line.
- Likewise, brokerage of water quality parameters (CHL, SPM, CDOM,  $K_D$ ) estimated from MERIS with IVM's North Sea algorithm (Pasterkamp *et al.* 2005), is straightforward because the WATeRS approach is generic, solving issues of handling file formats and automated updating.
- Adaptation to a new region requires a new subscription ID for the MODIS ftp services, and a new projection in the AML (figure 1).

Users of environmental and oceanographical data have multidisciplinary interests, and would like to combine different types of data of a certain geographical area (Eleveld *et al.* 2003a). WATeRS allows integration and comparison of different datasets on different levels, and is targeted towards visualization and grid query. For users holding their own GIS data, we facilitate combination of distributed datasets.

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